Department of Interior North Central Climate Science Center Foundational Science Areas

NORTH CENTRAL CLIMATE SCIENCE CENTER

2014 Annual Report

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April 2015

Introduction to the North Central Climate Science Center

The North Central Climate Science Center (NC CSC) is one of eight regional CSC's under the National Climate Change and Wildlife Science Center (NCCWSC). Our mission is "To provide the best available climate science and tools to inform natural resource management within the North Central domain." The NC CSC is a collaborative, applied research group that works with others across our domain to unite climate science with management decisions. The North Central University Consortium (NCUC), comprised of nine university partners in the region, provides foundational science needs and additional opportunities for integration with climate science users.

The NC CSC is dedicated to being a "Resource for Vulnerability assessment, Adaptation, and Mitigation Planning" (Figure 1). The ReVAMP concept is a centralizing theme that coordinates research done through the NC CSC and provides a mechanism by which the NC CSC can help serve stakeholder needs. The ReVAMP concept builds on three Foundational Science Areas led by the North Central University Consortium members. The three Foundational Science Areas offer an integrated approach to informing resource managers and researchers in our region:

- ***Climate Drivers:*** Understanding and quantifying drivers of regional climate changes.
- ***Impact Analysis:*** Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components.
- ***Adaptation:*** Characterizing adaptive capacity of communities and natural resources.

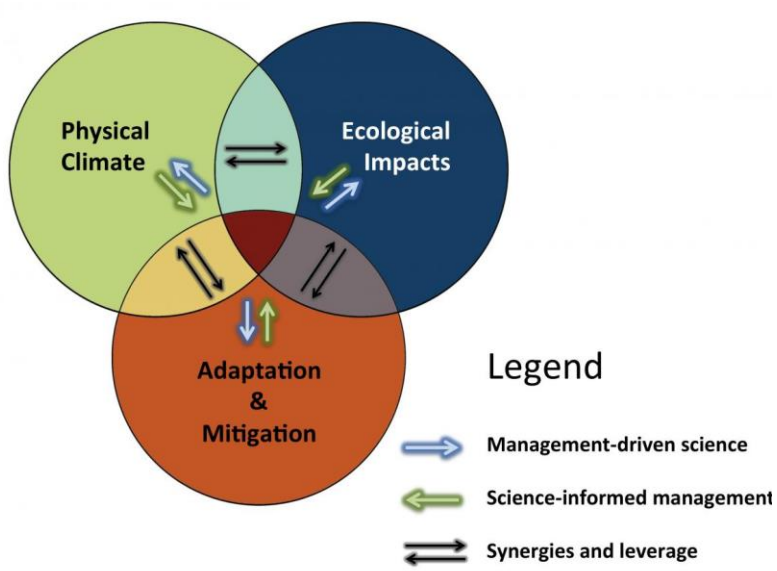

Figure 1. The three synergistic NC CSC foundational science areas include physical climate, ecological impacts, and adaptation & mitigation.

The strength of the ReVAMP concept is *bringing state-of-the-science climate information into simulation of ecological impacts in a collaborative, co-production of knowledge with scientists and managers*. The NC CSC is bringing computing tools, climate data, and management needs together to address complex situations and help stakeholders explore possible future scenarios. The NC CSC takes advantage of the Resource for Advanced Modeling, which provides an opportunity to collaboratively address the inherently complex integration of climate data into ecological modeling in a way that directly supports resource management decision making in a changing climate.

Figure 2. The Resource for Advanced Modeling (RAM) "VisWall" is a bank of 24 wall-mounted monitors in a 6x4 array that can be used for displaying large or numerous GIS datasets, photos, or other data products. The image here demonstrates three models of cheatgrass distribution in the western US.

The vision for the NC CSC is a coordinated and integrated regional approach to the management of the nation's land, water, fish and wildlife, and cultural heritage resources that utilizes the best possible understanding of past, present, and future climate in the decision process. Technical components are vital to implementing this vision via downscaling and regionally informed climate projections, ecological response models, and assessing social ecological vulnerabilities and adaptation planning.

The NC CSC activities are organized to provide the best available climate science and inferences on impacts and adaptation strategies for natural resource management entities within the North Central Domain. The NC CSC provides the knowledge and information needed by decision makers in the region so that a more complete understanding of potential impacts and adaptation strategies for a broad range of natural, cultural, energy, and other resource management activities is available. This knowledge and information exchange is provided through the ReVAMP platform to help interpret an array of climate information on changes, impacts, and responses. The aim of these activities is to develop integrated information relevant to our natural resource managers and to ensure that these managers have access to products AND can use them in their decision-making process. The NC CSC is directing its five-year science agenda toward science delivery through ReVAMP. Co-development of research products with managers working in partnership with research groups is a key component of our ReVAMP development efforts.

The NCUC has assembled a team of researchers to lead integrated research activities to enable the NC CSC to provide climate-relevant information to guide decision-making in the region. That is, the NCUC is providing the scientific foundation to be used within the ReVAMP.

Fundamental Science for the ReVAMP: Foundational Science Areas Research

The ReVAMP concept has served as a centralizing theme to coordinate research done through the NC CSC, and will also provide the mechanism by which the NC CSC can help serve stakeholder needs. NCUC efforts are organized around the three foundational research themes, which provide an integrated approach to inform resource managers and researcher in our region:

- Understanding and quantifying drivers of regional climate changes;
- Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components; and
- Characterizing vulnerabilities, adaptive capacity, and management response options of communities and natural resource.

Collaboration between decision makers, the climate modeling community, and researchers within the NCUC enhanced the integration of relevant climatological, ecological, energy, cultural, and management disciplines. Specifically, NCUC research includes:

- Region-specific approaches for developing targeted climatological information that respects the full range of temporal and spatial scales of climate processes in order to understand vulnerability of conservation targets to changing climate and opportunities for renewable energy given future climate scenarios.
- Capacities to provide enhanced climate information at relevant spatial and temporal scales, both for historical climate and projections of future climate.
- Ecological response modeling with enhanced climate information that respects non-stationarity.
- Social-ecological vulnerability and adaptation response studies of the social-ecological system

Research coordination activities have been carried out through discussions with university consortium members, LCC leaders, and other federal and tribal partners associated with the Stakeholder Advisory Committee for the NC CSC. Research activities in three Foundational Science Areas of focus are being designed and implemented to build on our initial community analytical platform to evaluate impacts and response options for management entities to consider. The Foundational Science Areas - extreme climate dynamics, impact analysis, and adaptive capacity and decision making -are described below.

NC CSC Foundational Science research incorporates the three concepts within a social-ecological system framework. This approach allows for better integration of research findings into a solution-oriented decision-making process due to the enhanced awareness of social dimensions of changes and impacts across the North Central region. This framework allows for specific research to be carried out within certain disciplinary domains while providing a platform to link various findings within the system framework.

The NC CSC used directed funds in 2014 to support NCUC efforts to continue work in the three foundational science areas to address climate drivers (with a focus on drought), impacts, and adaptation. The details of that work are given in the following three sections. The final summary section describes how these foundational research areas will persist through science teams, and how synergistic research activities have been identified to further develop linkages between these elements to enhance the delivery and synthesis of information to the management process, including vulnerability assessments, adaptation, and mitigation.

Foundational Science Area #1: Understanding and Quantifying Drivers of Regional Climate Changes

Team Lead: Joseph Barsugli, University of Colorado, Boulder
Co-Investigator(s): Imtiaz Rangwala (NOAA)

Understanding climate drivers is a central theme for all CSCs. Informing the north-central management community on the latest science related to climate drivers in the region and communicating the potential effects is a fundamental and critical element of the NC CSC ReVAMP model. The climate in the north-central domain is driven by large-scale patterns in atmospheric circulation, the region's complex topography, and effects due to the nature of the local land cover. The multi-scale nature of these climate drivers creates patterns of mean climate, climate variability, and climate change that are characterized by dramatic gradients in seasonal and annual temperature, effective moisture, and wind. The resulting climatic variability determines the diversity and distribution of habitats that support species and ecosystems and impacts the potential renewable energy resources for the area. It is necessary, therefore, to use region-specific approaches for developing targeted climatological information that respects the full range of temporal and spatial scales of climate processes in order to understand vulnerability of conservation targets to a changing climate and opportunities for renewable energy given future climate scenarios.

Related Activities and Deliverables

This research focus provides climate information across the region that will be tailored to resource management decision-makers' needs, and informs researchers on the drivers of change across an array of natural and cultural resource areas. This information will be analyzed over historical periods and will include projections of a variety of future climate scenarios.

Specific 2014 deliverables for the Climate Drivers team include:

- Climate Postdoc Appointment at CIRES/NOAA/Western Water Assessment to assist with the Climate FSA proposal submitted by J. Barsugli on Evapotranspiration Research
    - Formed a search committee (Joe Barsugli, Mike Hobbins, Ben Livneh), and put together a comprehensive position description
    - From more than 60 applicants, a selected few were interviewed and ranked. Three informal offers in the first round were all declined by the applicants because of various personal reasons.
    - There were 2nd round of interviews of four candidates; one offer was made and declined
    - In 2015, Candida Dewes, one of the candidates interviewed earlier and selected was re-approached (by Rangwala and Barsugli). She has been offered the position, has accepted it, and joins on July 1, 2015.
- Evapotranspiration Research Activities across CIRES/NOAA, NIDIS & NC CSC funded projects *(Large effort with several different activities)*
    - Organized a half-day mini-workshop (May 6, 2014) to introduce a group of ecologists to issues surrounding evapotranspiration (ET) and how to best include it in our models of the impacts of climate change on species distributions and other ecological processes.
    - Interacted with Mike Hobbins (NIDIS), Helen Sofaer (NC CSC management-focused project – Surrogate Species) and Ben Livneh (CIRES) and others on ET related research activities.
    - Explored sensitivity of ET to atmospheric drivers in collaboration with Mike Hobbins
    - Obtained ET sensitivity code/ transferred to MATLAB
    - Created local archive of CMIP5 model data of ET drivers, and performed preliminary test of ET calculations
    - Worked with Desert Research Institute (DRI) scientists, Justin Huntington and Dan McEvoy, on Evaporative Demand Drought Index (EDDI).
- Habitat Modeling efforts with CNHP & CPW: Partnered with NC CSC (Brian Miller), Colorado Natural Heritage Program (CNHP) and Colorado Department of Parks and Wildlife to provide

guidance on use of climate scenarios and data for habitat modeling via two all-day meetings and email consultations.

- Prepared several guidance documents for climate data use
    - This information is developed from responses to requests from researchers in NC CSC.
    - Comparing two methods for incorporating climate change into impacts modeling "perturbing past history" vs. "jump to model space".
    - How to interpret "model space" results in terms of the real world (e-mail correspondence with Helen Sofaer)
    - Why standardized indices may not be good predictors for species distribution models.
    - Climate Model Averaging and ANOVA - understanding when and how to average climate model results in the context of variance among climate models due to the main sources of uncertainty (with Colin Talbert at NC CSC).
- Compilation of Evapotranspiration (ET) Datasets: Listed and described (including metadata) a comprehensive array of available ET products in collaboration with Gabriel Senay at NC CSC
- Gridded Wind Dataset (Ongoing Task): Wrote the requirements and plans for producing a gridded wind dataset for western US. Established contacts at the National Renewable Energy Lab (NREL), e.g. Bri-Mathias Hodge, to access their high resolution modeled wind datasets. Consulted with Jim Wilczak (meteorologist) at NOAA's Physical Sciences Division. Also collaborated with Steve Running, Jared Oyler and Ruben Behnke at University of Montana.
- Webex Conference on Climate Model selection: Organized a conference Feb 12, 2014, titled "Selecting climate models for use in modeling ET for the prairie potholes region". This involved participation from distinguished scientists such as Richard Seager from the Lamont-Doherty Earth Observatory.
- NCPP manuscript: Worked with Andrea Ray from NOAA's Physical Sciences Division on "NCPP" manuscript that focuses on tracking and evaluating use of climate data in the first round of NC CSC funded projects.
- Climate FSA proposal for 2014-17: Wrote Climate FSA proposal of work for 2014-17 on research to evaluate the water balance, and particularly evapotranspiration, in the Northern Great Plains.
- Consultation with NC CSC staff on climate datasets: In particular with Marian and Colin Talbert

Foundational Science Area #2: Impacts and Vulnerability: Connecting Climate Drivers to Management Targets

Team Lead: Andrew Hansen, Montana State University
Co-Investigator(s): Arjun Adhikari (Montana State University)

Whereas climate drivers are a fundamental research component for the CSCs, they are often not the primary concern for most management issues. For example, land managers are often more concerned about animal populations or ecosystem services than they are about changes or trends in annual average temperature or precipitation. Yet climate drivers are linked to the conservation targets of concern. This research element is directed toward understanding and quantifying that linkage through ecological response models. Ecological response models, as enumerated in Glick and others (2011) help bridge between climate information and management goals.

This research area looks at leveraging ongoing and active research and expertise in ecological response models where translational climate analysis can advance that work. The connection to management actions links this research area to the adaptation and decision-making research area listed below. The

NC CSC is looking to build ecological response models that can both (a) be improved with enhanced climate information that respects nonstationarity and (b) serve management issues that have been prioritized by the stakeholders. The ReVAMP infrastructure facilitates these connections and interactions. The related research in this focus area must be open to and agile enough to iterate with both the climate-drivers research component and relevant resource management goals and objectives.

Related Activities and Deliverables

The impacts research area provides analysis of the relationship between ecological vulnerability to different exposure and sensitivity of system components and climate effects and drivers to address the nature of the vulnerability. It builds on observations available in the region and utilizes an ensemble of models to enhance the understanding of vulnerability to natural and cultural resources in the region. The vulnerability framework provides an analytical process to identify exposures and sensitivities of a system together, as well as highlighting sensitivities of separate parts of the system. Analysis of vulnerability will incorporate regional and temporal aspects to inform managers and researchers about interactions between factors and temporal dimensions of these interactions.

Specific 2014 deliverables for the Impacts team include the following:

- A new postdoctoral associate, Arjun Adhikari, was hired at Montana State University to take the place of Nathan Piekielek who moved to a new position (Hiring Lead: Hansen).
- A draft hydrological analysis of the Greater Yellowstone Ecosystem's montane meadow condition was performed using MODIS data and has been loaded into Sciencebase (Analysis Lead: Debinski).
- Species distribution maps and woody encroachment maps for montane meadows in the Greater Yellowstone Ecosystem have been created and loaded into Sciencebase (Mapping Lead: Debinski)
- A manuscript was submitted to Forest Ecology and Management entitled, "Which tree species and biome types are most vulnerable to climate change in the US Northern Rocky Mountains?" in November 2014 (Lead Author: Hansen)
- A manuscript was submitted entitled, "Projected future changes in spring snow pack and late summer soil water deficit suggest decline in habitat suitability for most forest species in the Greater Yellowstone Ecosystem, U.S." in May 2014 (Lead Author: Piekielek)
- A manuscript was published in Ecological Applications in April 2014 entitled, "Exposure of U.S. National Parks to land use and climate change 1900-2100" (Lead Author: Hansen)
- A technical report was completed for the USDA Forest service entitled, "The ecology and management of moist mixed-conifer forests in eastern Oregon and Washington: a synthesis of the relevant biophysical science and implications for future land management" (Lead Author: Stine)

Foundational Science Area #3: Characterizing Adaptive Capacity of Stakeholder Communities and Informing Management Options

Team Leads: Dennis Ojima and Shannon McNeeley, Colorado State University

Connecting to decision makers is one of the main operating principles for the center and integral to its mission. This connection is not always obvious or automatic; it requires not only a strong research program but also a healthy infrastructure for transition, a strong interface with the user community, and continuous evaluation of the process (National Academy, 2000). This research area ensures that the NC CSC has these key components in place.

Vulnerability and adaptive capacity issues come into play in both the 2nd and 3rd steps of the Glick and others (2011) framework. Understanding and evaluating social vulnerability and the adaptive capacity of social-ecological systems in the north central region should be an integral component in the development of integrated science to inform management strategies to deal with climate change. The vulnerability of social and natural resources and the adaptive capacity of the social-ecological system vary across the region due to local, state, tribal, and regional accessibility to social-ecological capital resource assets. The science done through the NC CSC aims to work toward understanding these complex interactions in the region and how they are, or can be, used for implementing adaptation strategies.

To identify management targets and implement management options, it is imperative to understand the social-ecological context and drivers. The NC CSC is very committed to identifying end users' needs and understanding and facilitating the incorporation of climate science into management decisions through qualitative and quantitative decision support tools. As such, a primary focal area for the region is drought, and the Drought Risk and Adaptation in the Interior (DRAI) project, focusing on resource managers' knowledge and observations about drought impacts, drought indicators, livelihoods affected, and adaptive capacity and barriers to respond is a core activity of the adaptation team.

Related Activities and Deliverables

This adaptation science focus area provided a critical analysis of how the different management entities represented on the Stakeholder Advisory Committee (SAC) and across the region have an ability to implement adaptation and mitigation strategies. This analysis will evaluate the options available to these entities to both address the impacts on the system and identify potential vulnerabilities. This information will provide a framework to build capacity to cope or respond to different stressors. Specific 2014 deliverables for the Adaptation team include the following:

- Annual Report completed for the Drought Risk and Adaptation in the Interior project: McNeeley, S.M. Beeton, T., Ojima, D., 2014 Drought Risk and Adaptation in the Interior (DRAI) First Annual Report, North Central Climate Science Center, Colorado State University, Fort Collins, CO.Miller, B.W., & J.T Morisette (2014). Integrating Research Tools to Support the Management of Social-Ecological Systems under Climate Change .
- Developed a research approach to study drought based on the Social Ecological Systems Conceptual Framework that incorporates a bottom-up approach through grounded theory methods.
- Continued DRAI interviews with tribal members at Wind River Reservation, Wyoming and integrating those with the other two DRAI case studies in northwest Colorado and southwest South Dakota in an ongoing effort to build the management-focused interviews for the region.
- In September 2014, tribal representatives, scientists, and members of state and federal governments gathered in Rapid City, SD, the ultimate goal of which was to discuss drought and climate change, drought impacts, early warning systems and planning for extreme events with the Missouri River Basin tribes. The workshop was sponsored by the National Integrated Drought Information System (NIDIS). The NC CSC led the coordination of an Inter-Tribal Buffalo Council (ITBC) pre-workshop Representatives from tribes throughout the Missouri Basin region and beyond attended. In addition to the NC CSC and ITBC, partners included NIDIS, the USDA Northern Plains Climate Hub, and the National Drought Mitigation Center at University of Nebraska, Lincoln. The NC CSC continues to support the ITBC in the implementation of their USDA Conservation Integration Grant on Drought Resiliency and Adaptation for their 60 tribal members.

- The NC CSC and other organizations are providing technical support to the Eastern Shoshone and Northern Arapaho tribes on the Wind River Reservation in Wyoming as they establish reservation-wide drought monitoring and planning. NC CSC's Shannon McNeeley, Colorado State University and Gary Collins, Wind River Reservation, are the lead coordinators in this ongoing effort to help the tribes develop a drought monitoring system and drought plan that addresses all 15 beneficial uses of water as identified in the Wind River Tribal Water Code. They are working closely with the Wind River Tribal Water Engineer's office and the Water Resources Control Board. Other participating organizations include the National Drought Mitigation Center at University of Nebraska, Lincoln , University of Wyoming's EPSCoR program, the University of Wyoming Water Resources Data System and State Climate Office, the High Plains Regional Climate Center, the NOAA National Integrated Drought In- formation System, the USDA Northern Plains Climate Hub, and the University of Colorado Boulder-NOAA Western Water Assessment, among many other local tribal partners, water user groups, and state and federal agencies.
- McNeeley led the coordination of a workshop that took place on Oct. 21-22 at Fort Washakie, WY. Workshop sessions and discussion focused on local drought impacts and needs for natural resource management and decision making during drought, the availability of drought and water monitoring data, and on how the tribes could supplement state and federal monitoring programs. Strategies include enlisting volunteer observers on the reservation for the Community Collaborative Rain, Hail and Snow network, and installing and managing weather stations and stream gauges. Participants said that having good climate data will help the tribes better manage the area's water for all of the 15 beneficial uses during times of shortage. A follow-up workshop was held in March 2015 to finalize the summary and to do training on drought planning.
- The adaptation team worked in collaboration with the USGS Fort Collins Science Center to develop a Mendenhall Fellowship request for proposals to hire a postdoc to focus on adaptation strategies and barriers in the north central region. This position will begin in 2015 and review of proposals and interviews was conducted in the winter and spring of 2015.
- The NC CSC adaptation team is developing a social vulnerability assessment project with the Colorado Bureau of Land Management (led by McNeeley) to inform their state climate adaptation planning strategy development. This project is in collaboration with Western State University (co-lead Corrie Knapp) and other partners in the state.

Foundational Science Area Teams

Synergies and continuation of teams

The NC CSC five-year science agenda is founded on the three focus areas described above. We have maintained work in these areas, continuing and building on the integrated work among the three foundational science teams, and have integrated that work into the other work at the Center and in the region.

Financial support

The initial foundational science work was funded in 2013, continued through 2014 (this report), and will continue through 2015. The NC CSC provides resources to each team. Each team has a leader who is responsible for organizing the work within that area as well as connecting the work within that area to both the other foundational science areas and into the ReVAMP science delivery mechanism. Team resources can support time for the team leader, a post-doctoral researcher, and team workshops. It is

up to the team lead, working in collaboration with the NC CSC, to utilize the budget to maximize the impact of each team.

Selection of team leads and governance

Long-term planning efforts on how the NCUC will be able to continue support of research efforts in the region will be carried out by the lead of these research elements. As such, the NCUC helps to lead the selection of the team leads. The team leads, continuing from 2013, are Dr. Joseph Barsugli for climate (University of Colorado), Dr. Andrew Hansen for impacts (Montana St University), and Dr. Dennis Ojima for vulnerability and adaptation responses (Colorado St University). These leads continue in their leadership role as it was being defined at the May 2012 science-planning workshop.[1] Their initial interest and work contributed to the NC CSC five-year plan. In 2015, NC CSC will revisit the selection of team leads; with current team leads being eligible for consideration to continue if they are so inclined. Once selected, the team leads will be given funding as described above and provide support as described below.

The NC CSC hosted a joint meeting of the Foundational Science Area teams in Fort Collins, February 2014. This meeting allowed the team leads and other project representatives to come together to discuss progress and opportunities for collaboration and cross-sharing of data.

Consultation to assist with directed work

In addition to the specific funding dedicated to each team lead, the team leads act as consultants to the NC CSC for recommendations and insight on how to spend directed funds available through the center. In 2013 and 2014 the NC CSC spent approximately ½ of its research funds on solicited/competed work and maintain roughly ½ for directed funding. As competed funds are awarded, the foundation science team leads have been consulted with to evaluate those projects and help guide the use of directed funds to a) augment the work of the solicited projects and b) fill any critical climate-science research gaps.

Assistance with coordination

The foundational science teams help to ensure coordination with other national and regional initiatives. Priority regional coordination opportunities include working with the NOAA's Western Water Assessment and Landscape Conservation Cooperatives. Priority national level coordination opportunities include working with NOAA's National Climate Projection and Prediction program, the National Climate Assessment (NCA; disseminating information from the 2013 NCA and helping prepare information for the 2017 NCA), and the National Center for Atmospheric Research (NCAR).

Support for the mission of the NC CSC

Finally, it is the ultimate objective of the three Foundational Science teams to support the mission of the NC CSC to deliver the best possible climate-related science to regional resource managers. Currently, the lead investigators for each of the 3 elements (i.e., climate, impacts, and adaption) routinely communicate on research efforts and prioritization of research activities to enhance the linkage of research products. This collaboration across elements improves efficiency, understanding and utility for use in natural resource management decision making. With the resources and objectives outlined here, the NC CSC hopes it will be possible to further enhance coordination among elements to develop a more integrated climate-ecological-social system framework.

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[1] *http://www.doi.gov/csc/northcentral/upload/NC-CSC-science-planning-workshop-report-May-2012.pdf.*

Cross-project meetings (face-to-face and virtual) among the foundational research groups, other funded investigations, coordinated efforts, and management entities working with the NC CSC have been and will continue to be held to co-develop research products and translational materials that are relevant, useful, and useable for natural resource management decisions. The Foundational Science teams are playing a major role in the development of this integrated synthesis of research products aimed to meet natural resource management needs. An important product of this integrated research activity will be a development of synthesis papers outlining the implications of climate change effects on natural resources in the region and the potential response options that may be feasible. In 2014, teams focused on writing manuscripts that were relatively contained within the individual foundational science areas. While they will continue to write manuscripts directed by their individual research directions, 2015 will see the teams collaborate more intensively as they progress in their integrative activities and data sharing to produce synthetic results and management recommendations.

Management-focused Projects

The NC CSC funds competitively selected multi-year projects with a clear "articulation of the decision that is being considered and how it addresses important Department of Interior land, water, fish and wildlife, or cultural heritage resources in the region" and the inclusion of resource management decision makers as collaborators and/or investigators. These solicited projects help connect the foundational science work with critical resource management needs and are helping to define the specific capacity that will be built into the ReVAMP framework (link to revampclimate.colostate.edu projects).

Current and Continuing Management-focused Projects

1. NATURAL RESOURCE MANAGEMENT DECISION-MAKING UNDER CLIMATE UNCERTAINTY: BUILDING SOCIAL-ECOLOGICAL RESILIENCE IN SOUTHWESTERN COLORADO

Principal Investigator(s):
Nina Burkardt and Rudy Schuster, USGS Fort Collins Science Center
Co-Investigator(s):
Renée Rondeau (Colorado State University, Colorado Natural Heritage Program); Betsy Neely (The Nature Conservancy- TNC); Marcie Bidwell (Mountain Studies Institute - MSI); Laurie Yung (University of Montana - UM); Carina Wyborn (UM); Rudy M. Schuster (USGS); John Sanderson (TNC); William Travis (University of Colorado - CU); Daniel Williams (USDA Forest Service Rocky Mountain Research Station); Daniel Murphy (University of Cincinnati)

In southwestern Colorado, climate change includes higher temperatures, more frequent and prolonged drought, accelerated snowmelt, larger and more intense fires, more extreme storms, and the spread of invasive species. These changes put livelihoods, ecosystems, and species at risk.

To help human and natural communities cope with climate change, this project is creating opportunities for scientists, land managers, and affected residents to learn from each other and identify actions that each can take individually or collectively to reduce the negative impacts of climate change in the San Juan and Gunnison Basins in Colorado. These adaptation strategies and the processes that created them are being documented by the participating scientists to assist communities elsewhere in identifying goals and actions that conserve key species, ecosystems, and resources, and address the needs of local communities and natural resource managers in the face of a changing climate.

2014 Activities, Deliverables and Progress

- Refined social science research design: Refined questions and workplan; Developed a sampling frame, interview guides, and plan for pilot interviews; conducted review of relevant social theory and resources on the San Juan Basin.
- Developed a set of actionable adaptation strategies for selected vulnerable ecosystems/species that identify the location, timeline and action steps needed for effective implementation
- Nina Burkardt, Renee Rondeau, and Betsy Neely gave presentations (on social, vulnerability assessment, and SECR project) to the Gunnison Climate Working Group stakeholders in January 2014 in Gunnison.
- Developed narrative scenarios of landscape change and adaptation/ conservation targets
    - Develop "landscape-scale" and "target-specific" climate scenarios to inform the narrative scenarios.
    - Develop narrative scenarios of landscape change with an emphasis on the targets based on range, variability, and uncertainty in regional climate projections; submit for review by scientific experts in relevant fields; edit and finalize.
- Completed individual interviews (April-June 2014)
    - Reviewed relevant social science research (Gunnison; San Juan already completed).
    - Refined interview guides and submitted to basin team for review.
    - Refined sample in consultation with basin team and key stakeholders.
    - Worked with Ute Mountain Ute tribe to secure permission to interview tribal members.
    - Conducted semi structured in-depth interviews (30-40 in San Juan, 30 in Gunnison).
    - Conducted rapid analysis.
    - Conducted in-depth analysis.
- Hosted focus groups (focus group discussions or as Agency-specific workshops) (June-July 2014)
    - Planned and held focus groups interviews
    - Utilized narrative scenarios to engage focus group participants in (1) talking about decision-making under uncertainty, (2) impacts and responses to future change, and (3) approaches to adaptation.
    - In the San Juan, the focus groups were conducted as part of four agency-specific workshops which were utilized to collect social science data and to build agency adaptive capacity. Workshops engaged participants in developing an initial list of possible adaptation strategies that were used to inform an adaptation workshop.
    - Analyzed focus group results
- Developed ecological response models
    - Formed small teams for target modeling work to assess current and future impacts under climate scenarios
    - Set up Confluence site for target literature and other project documents.
    - Held small workshop in June, 2014 to draft ecological response models for Gunnison targets and sought local partners/experts to review.
    - Drafted management objectives.
    - Built in CNHP/CPW/NC CSC habitat suitability model results
    - Revised ecological response models to include social, ecological and climate drivers.
- Adaptation workshop (September-November 2014)
    - Held ACT framework workshop to develop strategies for targets
    - Identified intervention points
    - Drafted social ecological climate adaptation strategies for targets

- Sent strategies out for review and finalize based on review comments
- Validated and prioritized strategies

2. SURROGATE SPECIES FOR WETLAND-DEPENDENT BIRDS IN THE PRAIRIE POTHOLE REGION: SELECTION, EVALUATION, AND MANAGEMENT APPLICATION IN THE FACE OF CLIMATE CHANGE

Principal Investigator(s):
Susan Skagen (U.S. Geological Survey, Fort Collins Science Center) and Barry Noon (Dept Fish, Wildlife and Conservation Biology, Colorado State University)
Co-Investigator(s):
Helen Sofaer (Colorado State University); Valerie Steen (USGS Fort Collins Science Center); Ben Rashford (University of Wyoming); John Stamm (USGS South Dakota Water Science Center); Kevin Doherty (USFWS, Prairie Pothole Joint Venture); Neil Niemuth, (USFWS, Habitat and Population Evaluation Team); Cami Dixon (Zone Biologist, USFWS Region 6, National Wildlife Refuge System); Mark Chase (Director, USFWS Natural Resource Program Center); Natalie Sexton (Chief, Human Dimensions Branch, USFWS Natural Resource Program Center); Lee O'Brien (Ecologist, USFWS National Wildlife Refuge System), Socheata Lor (USFWS, Regional Inventory and Monitoring Coordinator), Rick Nelson and Mike Olson (Plains and Prairie Pothole Landscape Conservation Cooperative (PPPLCC))

The Prairie Pothole Region spans parts of North and South Dakota, Minnesota, Montana, Iowa and south-central Canada and contains millions of wetlands that provide habitat for breeding and migrating birds. Because it is the continent's most important breeding area for waterfowl, conservation and management largely focuses on protecting habitat for nesting ducks. However, other wetland-dependent birds also rely on this region, and it is important to understand the degree to which habitat conserved for ducks provides habitat for other species, and how the quality of this habitat will be affected by climate change.

The Surrogate Species team is testing whether waterfowl are effective representatives, or surrogates, for other wetland-dependent birds by predicting how climate change will affect habitat suitability for waterfowl and other species. They are also considering how climate change is likely to affect land-use patterns and agricultural conversion risk, and are using these predictions to identify areas of the landscape where both waterfowl and other species are expected to have suitable habitat in the future. This research will help managers to efficiently direct their resources towards conserving areas that will provide habitat to a broad suite of species.

2014 Activities, Deliverables and Progress

- The Surrogate Species team has used two approaches to identify areas of the landscape that are likely to provide suitable habitat for wetland-dependent birds under future climatic and land use conditions: through direct models of the effects of climate on the distribution and abundance of wetlands, and to model how climate may affect land conversion from grassland/ranching to agriculture.
- Valerie Steen gave a presentation entitled, "Vulnerability of Breeding Waterbirds to Climate Change in the Prairie Pothole Region, U.S.A." in December, 2014.
- Outreach to land managers is ongoing, including a summer 2014 presentation to members of the USFWS and the PPP LCC to share information on climate science and the most recent climate projections, results of species distribution models and assessments of vulnerability under climate change, and theory on surrogate species. This allowed the team to get feedback on and modify some methods to reflect managers' suggestions.

- Manuscripts are in progress.
- The Surrogate Species team has modified their research approach, particularly with regards to the first goal of selecting and validating surrogate species. Instead of their original approach, they are analyzing surrogate relationships using a type of mixture model referred to in the literature as species archetype models to create clusters of species; a surrogate can then be selected from each cluster, and would be assumed to represent other members of its cluster. This project's preliminary results suggest that species archetype models may be broadly applicable tools for clustering species as part of surrogate species selection.
- Projections of the distribution and abundance of wetlands under climate change indicate that for 10 GCMs and RCP 8.5, wetland densities midcentury (2041-2070) will be highest in the area where densities are currently highest.

3. INFORMING IMPLEMENTATION OF THE GREATER YELLOWSTONE COORDINATING COMMITTEE'S (GYCC) WHITEBARK PINE (WBP) STRATEGY BASED ON CLIMATE SCIENCES, ECOLOGICAL FORECASTING, AND VALUATION OF WBP-RELATED ECOSYSTEM SERVICES

Principal Investigator(s):
Cathy Whitlock and Andrew Hansen, Montana State University
Co-Investigator(s):
GYCC WBP Subcommittee: Karl Buermeyer (Bridger Teton NF); Kristen Legg (NPS I&M); Dan Reinhart, (YNP). GYCC: Virginia Kelly (Executive Coordinator). USGS Northern Rocky Mountain Science Center: Greg Pederson. Great Northern LCC: Tom Olliff (Co-coordinator). NPS I&M: John Gross, Bill Monahan. University of Montana: Helen Naughton (Economics Dept.). Montana State University: Virginia Iglesias, Todd Kipfer (Institute on Ecosystems); Nathan Piekielek (Ecology Dept.); Elizabeth Shanahan (Political Science Dept.); Arjun Adhikari.

The goal of this project is to inform implementation of the Greater Yellowstone Coordinating Committee (GYCC) Whitebark Pine (WBP) subcommittee's "WBP Strategy" based on climate science and ecological forecasting. Objectives are: 1. Forecast ecosystem processes and WBP habitat suitability across the Greater Yellowstone Area (GYA) under alternative IPCC future scenarios; 2. Improve understanding of possible response to future climate by analyzing WBP/climate relationships in past millennia; 3. Develop WBP management alternatives; 4. Evaluate the alternatives under IPCC future scenarios in terms of WBP goals, ecosystem services, and costs of implementation; and 5. Draw recommendations for implementation of the GYCC WBP strategy that consider uncertainty.

WBP is a keystone and candidate endangered species that has undergone high levels of mortality related to climatic warming. The GYCC WBP Subcommittee has developed over the past decade a strategy for WBP in the GYA, but without adequate information on climate change. The subcommittee is participating in this project because of their high interest in using climate science to enhance implementation of the strategy. Ecosystem processes and WBP habitat suitability are being forecast under downscaled future scenarios to 2100 with existing funding. Paleo data from GYA is being used to quantify WBP/climate relationships over the past 15,000 years and growth rates during extreme climate events over the past 800 years. The white bark pine team is developing four WBP management alternatives in a workshop at the NC CSC RAM, consistent with the GYCC WBP Strategy. The team is evaluating these alternatives relative to WBP status (viability and ecosystem function), costs of implementation, and public valuation of change in ecosystem services using conjoint analysis and public surveys. A scenario planning workshop is planned to derive recommendations based on both the results and uncertainty in the results. These recommendations can thus be immediately acted upon by the GYA

management community and the approach and methods will be readily applicable to the several other tree species that are undergoing die-offs under changing climate.

2014 Activities, Deliverables and Progress

- Several Changes have been made to the study approach, including: 1) WBP management alternatives are being developed in various venues in the GYE, not at the RAM in Fort Collins, due to logistic issues. 2) The consequences of the alternative management strategies on ecosystem function will not be evaluated because information and technology are inadequate for such an analysis. 3) Costs of implementing management strategies will not be quantified because agency collaborators declined this on the basis that such accounting is already being done in house. 4) The social survey work has been expanded in content and geographic scope to deal more broadly with climate change.
- The ecological forecasting methods in the proposal were used to project WBP climate suitability in the GYE and these are detailed in Chang et al. 2014. In addition to what was originally proposed, a meta-analysis of WBP of WBP climate suitability and vulnerability across the Northern Rockies was completed (Hansen and Phillips 2015).
- The methods in the proposal were used to evaluate WBP presence in the GYE throughout the Holocene using techniques including stratigraphic pollen data analysis, charcoal records, and radio-carbon dated pollen records.
- Analyses of WBP suitability is ongoing through 2015, and the social science research has shifted its focus to more broadly address WBP management and valuation in the context of climate change because information and technology are inadequate for the project's original goals. The survey is in development.

Manuscripts:

- Published: Chang T, Hansen AJ, Piekielek N (2014) Patterns and Variability of Projected Bioclimatic Habitat for *Pinus albicaulis* in the Greater Yellowstone Area. PLoS ONE 9(11): e111669. doi:10.1371/journal.pone.0111669.
- Published: Hansen, A.J. and L.B. Phillips, 2015. Which tree species and biome types are most vulnerable to climate change in the US Northern Rocky Mountains? Forest Ecology and Management 338:68-83.
- In Review: Iglesias, V., T.R. Krause, C. Whitlock. In Revision. Complex response of pine to past environmental variability increases understanding of its future vulnerability. PLOS ONE.
- In Review: Hansen, A.J., N. Piekielek, T. Chang, L. Phillips. In Review. Changing climate suitability for forests in Yellowstone and the Rockies. Yellowstone Science.
- In Preparation: Buermeyer, K., D. P. Reinhart, K. Legg, and V. Kelly. In Prep. Case Study: Whitebark Pine in GYE. Pages xx-xx in A. J. Hansen, D. M. Theobald, T. Oliff, and W. Monihan, editors. Climate Change in Wildlands: Pioneering Approaches to Science and Management in the Rocky Mountains and Appalachians. Island Press.
- In Preparation: Hansen, A.J., E. Barge, K. Ireland, M. Jenkins, M. Pillet, K. Legg. In Prep. Population Viability under Deteriorating Climate: Exploring "Windows of Opportunity" for Whitebark Pine in Greater Yellowstone. For Ecological Applications.
- In Preparation: Hansen, A.J., D. Theobald, T. Olliff, W. Monahan, editors. In Prep. Climate Change in Wildlands: Pioneering Approaches to Science and Management in the Rocky Mountains and Appalachians. Island Press.
- In Preparation: Piekielek, N., A.J. Hansen, T. Chang. In Prep. Past, present, and future climate shapes the vegetation communities of the Greater Yellowstone Ecosystem across elevation gradients. Pages xx-xx in A. J. Hansen, D. M. Theobald, T. Oliff, and W. Monihan, editors. Climate

Change in Wildlands: Pioneering Approaches to Science and Management in the Rocky Mountains and Appalachians. Island Press.

Conference presentations, seminars, webinars, workshops, or other presentations:

- Chang, T., A. Hansen, N. Piekielek. 2014. Estimating future suitable bioclimatic habitats for whitebark pine in the Greater Yellowstone under projected climates. Society for Conservation Biology North American Congress for Conservation Biology July 13-16, University of Montana, Missoula, Montana
- Chang, T., A. Hansen, T. Olliff, M. Pillet. 2014. Relevance of Climate Suitability Analyses for GYCC WBP Management Strategies in GYE. GYCC WBP Subcommittee Workshop. Bozeman, MT October 2014
- Hansen, A.J. Landscape Climate Change Vulnerability Project. Greater Yellowstone Coordinating Committee. Jackson, WY. March 2014.
- Hansen, A.J. Landscape Climate Change Vulnerability Project. NASA Ecological Forecasting annual meeting. Washington D.C. April 2014.
- Hansen, A.J. 2014. Assessing ecological vulnerability to climate change across the Great Northern LCC. Society for Conservation Biology North American Congress for Conservation Biology July 13-16, University of Montana, Missoula, Montana.
- Hansen, A.J. Which tree species are most vulnerable to climate change in the Northern Rockies? Climate Change Adaptation Regional Tribal Conference, Bozeman, MT. August 2014.
- Hansen, A.J. L.B. Phillips, T. Chang, N. Piekielek. 2014. Which tree species and biome types are most vulnerable to climate change in the US Northern Rocky Mountains? Yellowstone Biannual Science Conference Mammoth, WY, October 2014.
- Hansen, A.J. 2014. Land Use Change in the Greater Yellowstone Ecosystem: Past, Present, and Possible Future Patterns and Consequences. Jackson Wildlife Symposium, Teton Science School, Jackson WY. Dec 2014.
- Naughton, H., E.A. Shanahan. 2014. Valuation of Whitebark Pine in GYE Given Uncertainty. GYCC WBP Subcommittee Workshop. Bozeman, MT October 2014.

Newly Funded Management-focused Projects

Five new projects were selected for funding in December 2014. These projects will begin in the spring of 2015, and continue for 2-3 years depending on the project. While these projects are just getting off the ground, they contribute to understanding the NC CSC's future directions in research and partnership.

1. SCALING CLIMATE CHANGE ADAPTATION IN THE NORTHERN GREAT PLAINS THROUGH REGIONAL CLIMATE SUMMARIES AND LOCAL QUALITATIVE-QUANTITATIVE SCENARIO PLANNING WORKSHOPS

Principal Investigator(s):

Amy Symstad, Norther Prairie Wildlife Research Center; asymstad@usgs.gov. (Project Contact: Stephanie Manz, Administrative Officer, smanz@usgs.gov)

Co-Investigator(s):

Brian Miller [Colorado State University North Central Climate Science Center (NC CSC)], Nicholas Fisichelli [National Park Service (NPS)], Gregor Schuurman (NPS), Melinda Koslow (NPS), Andrea Ray [National Oceanic and Atmospheric Administration], Jonathan Friedman (USGS), Erika Rowland [Wildlife Conservation Society]. Cooperator: Marian Talbert (USGS, NC CSC), Partners: Milton Haar (NPS), Mike McNeill [U.S. Forest Service (USFS)], Wendy Ross (NPS), Cami Dixon [U.S. Fish & Wildlife Service (FWS)], Neil Shook (FWS).

Climate change is expressed in both regional climatic shifts (e.g., temperature and precipitation changes) and local resource impacts. Resource management in a changing climate is challenging because future climate change and resource responses cannot be precisely predicted. Scenario planning is a tool to assess the range of plausible future conditions. However, selecting, acquiring, synthesizing, and scaling climate information for scenario planning requires significant time and skills.

This project has three goals: 1) synthesize climate data into 3-5 distinctly different but plausible climate summaries for the northern Great Plains region; 2) craft summaries of these climate futures that are relevant to local land management units; and 3) apply these local summaries to further develop quantitative climate-resource-management scenarios through participatory workshops and simulation models. This team is engaging with multiple stakeholders in two focal areas within the region: southwestern South Dakota in the vicinity of Badlands National Park, and central North Dakota in the vicinity of Knife River Indian Villages National Historic Site. This effort will increase climate change planning efficiency in the region; promote collaborations across jurisdictions; and develop a prototype for a novel, efficient, and replicable form of scenario planning that could serve additional management units.

2. FORECASTING CHANGES IN SAGEBRUSH DISTRIBUTION AND ABUNDANCE UNDER CLIMATE CHANGE: INTEGRATION OF SPATIAL, TEMPORAL, AND MECHANISTIC MODELS

Principal Investigator(s):
Benjamin Poulter, Montana Institute on Ecosystems and Department of Ecology, Montana State University; benjamin.poulter@montana.edu (Project Contacts: Julie Geyer, Fiscal Manager; jgeyer@montana.edu)
Co-Investigator(s):
Peter Adler, Utah State University; Cameron Aldridge, USGS; Bethany Bradley, University of Massachusetts. John Bradford, USGS; Caroline Curtis, University of Massachusetts; Andy Kleinhesselink, Utah State University; Jen Pierce, Boise State University; Daniel Schlaepfer, University of Wyoming; Eric Thacker, Utah State University Extension. Mary Manning, US Forest Service; Renee Chi, Utah BLM; Robert Means, Wyoming BLM; Steve Torbit, Fish and Wildlife Service.

The future of sage grouse depends on the future of sagebrush, yet there is limited ability to anticipate impacts of climate change on sagebrush populations. Current efforts to forecast sagebrush habitat typically rely on species distribution models (SDMs), which are prone to a variety of well-known weaknesses. However, by integrating SDMs with complementary research approaches, such as historical data analysis and mechanistic models, it will be possible to provide increased confidence in projections of habitat vulnerability to climate change.

The goal of this project is to forecast the effect of climate change on the distribution and abundance of big sagebrush in order to inform conservation planning, and sage grouse management in particular, across the Intermountain West. The novelty of this work is the integration of model projections based on spatial, temporal, and mechanistic relationships between climate and sagebrush cover. The project will culminate in a working group meeting bringing together land managers and researchers to discuss how integrated metrics for climate vulnerability can be used to inform management. The team will take advantage of existing USGS infrastructures already in place to efficiently disseminate our final report to management agencies.

3. THE WIND RIVER INDIAN RESERVATION'S VULNERABILITY TO THE IMPACTS OF DROUGHT AND THE DEVELOPMENT OF DECISION TOOLS TO SUPPORT DROUGHT PREPAREDNESS

Principal Investigator(s):
Dr. Cody Knutson, Research Associate Professor and Leader of the Planning and Social Science Program, National Drought Mitigation Center (NDMC), School of Natural Resources, University of Nebraska-Lincoln, cknutson1@unl.edu (Project Contact: Jeanne Wicks, Director, Office of Sponsored Programs, University of Nebraska- Lincoln, unlosp@unl.edu)
Co-Investigator(s):
Mitchel Cottenoir, Tribal Water Engineer, Shoshone and Arapaho Tribes Office of the Tribal Water Engineer; Jennifer Wellman, Hydrologist, Wyoming Experimental Program to Stimulate Competitive Research (EPSCoR) Coordinator at Wind River Reservation; Dr. Shannon McNeeley, Research Scientist, Colorado State University/North Central Climate Science Center (NC CSC); and Mark Svoboda, Climatologist and Leader of the Monitoring Program, NDMC, University of Nebraska-Lincoln Project Management Team (PMT): The PIs listed above plus Northern Arapaho Tribal Liaison, Gary Collins, and Al C'Bearing, Baptiste Weed, Jim Pogue, Office of the Tribal Water Engineer

This project is conducting an interdisciplinary, technical assessment of key social-ecological vulnerabilities, risks, and response capacities of the Wind River Indian Reservation (WRIR) to inform development of decision tools to support drought preparedness. It is also providing opportunities for 1) development of tribal technical capacity for drought preparedness, and 2) educational programming guided by tribal needs, Traditional Ecological Knowledge (TEK), and indigenous observations of drought for tribal members, with a longer-term goal of transferring lessons learned to other tribes and non-tribal entities.

This project has foundational partnerships between the Eastern Shoshone and Northern Arapaho tribes of the WRIR, the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, the North Central Climate Science Center (NC CSC) at Colorado State University, University of Wyoming EPSCoR, and multiple government agencies and university partners. These partners are working together to develop decision tools to support drought preparedness. Other partners include the USDA Northern Plains Regional Climate Hub and NRCS, the Western Water Assessment at CU Boulder, NOAA National Integrated Drought Information System (NIDIS), the High Plains Regional Climate Center, US Fish and Wildlife Service, USGS, BIA, Great Northern LCC, and other North Central University Consortium scientists. The project's decision target is a WRIR Drought Management Plan that integrates state-of-the art climate science with hydrologic, social, and ecological vulnerabilities and risks, and identifies response capacities and strategies to support the Tribal Water Code and related resources management.

4. INFORMING ADAPTATION STRATEGIES FOR MAINTAINING LANDSCAPE CONNECTIVITY FOR NORTHERN ROCKIES WILDLIFE IN THE FACE OF CLIMATE CHANGE

Principal Investigator(s):
PI: Steven Hostetler (USGS, Northern Rocky Mountain Science Center) swhostet@usgs.gov; (Project Contacts: Judy O'Dwyer, Branch Chief, Operations & Communications, jodwyer@usgs.gov)
Co-Investigator(s):
Meredith McClure (Center for Large Landscape Conservation), Bray J. Beltrán (Heart of the Rockies Initiative); Yvette Converse & Tom Olliff (Great Northern Landscape Conservation Cooperative); John Pierce (WA Dept. of Fish & Wildlife, WGA Crucial Habitat Initiative Technical Team); Reed Kuennen (USFS Flathead National Forest); John Waller (NPS Glacier National Park); Deb O'Neill (Montana Fish, Wildlife &

Parks); Michael Whitfield (Heart of the Rockies Initiative); Melly Reuling (Rocky Mountain Partner Forum, Center for Large Landscape Conservation); Rob Ament (Center for Large Landscape Conservation)

Establishing connections among natural landscapes is the most frequently recommended strategy for adapting management of natural resources in response to climate change. The U.S. Northern Rockies still support a full suite of native wildlife, and survival of these populations depends on connected landscapes. Connected landscapes support current migration and dispersal as well as future shifts in species ranges that will be necessary due to our changing climate.

Working in partnership with state and federal resource managers and private land trusts, this team is working to 1) understand how future climate change may alter habitat composition of landscapes expected to serve as important connections for wildlife; 2) understand how wildlife species of concern are expected to respond to these changes; 3) develop climate-smart strategies to help stakeholders manage public and private lands in ways that allow wildlife to continue to move in response to changing conditions; and 4) explore how well existing management plans and conservation efforts are expected to support crucial connections for wildlife under climate change. Ultimately, this project aims to ensure that the iconic landscapes of the Northern Rockies and the wildlife they support endure in a changing landscape for the benefit of future generations.

5. UNDERSTANDING DYNAMICS OF LAND USE SWITCHING WITH SATELLITE AND FIELD LEVEL DATA IN CONTEXT OF CLIMATE VARIABILITY

Principal Investigator(s):
David A. Hennessy [Dept Economics and Center for Agricultural and Rural Development (CARD), Iowa State University; hennessy@iastate.edu], Christopher J. Anderson [Climate Science Program, Iowa State University, cjames@iastate.edu], Peter T. Wolter [Dept Natural Resource Ecology and Management, ptwolter@iastate.edu], Hongli Feng [Dept Economics, Iowa State University; hfeng@iastate.edu]
Co-Investigator(s):
Kaylan Carrlson (Manager of Conservation Planning, Ducks Unlimited, Inc.); Martha Kaufmann (Managing Director, Northern Great Plains, World Wildlife Federation US); Heather Johnson (Regional Private Lands Coordinator, US Fish and Wildlife Service); Scott McLeod (N. Dakota Private Lands Coordinator, US Fish and Wildlife Service); Adnan Akyüz (N. Dakota State Climatologist); Peter Bauman (S. Dakota State Univ. grassland extension specialist); Juan M. Murguia (Dept. of Agric. & Applied Economics, N. Dakota State Univ.); Ben Rashford (Dept. of Agric. & Applied Econ., Univ. of Wyoming); Susan Skagen (USGS, Fort Collins, Colorado); Rick Nelson (Plains and Prairie Pothole Landscape Conservation Cooperative).

What remains of the United States prairie ecosystem is threatened by economic forces and a changing climate. Grassland conversion to cropland in the Dakotas would imperil nesting waterfowl among other species and further impair water quality in the Mississippi watershed. This team is working with grassland conservation managers to better target the use of public and private funds allocated toward incentivizing grassland preservation on private lands in the Dakotas. They are assembling data on historical land switching in the area and on land conversion costs, and are analyzing crop vulnerabilities to weather and climate change.

The team is working to provide practical analytical tools to assess the likelihood of grassland conversion to cropping and of the costs of protecting these lands under different climate and economic scenarios.

These tools, together with insights they are obtaining from partners in the area allows them to work with land conservation managers to identify lands to target for grassland protection incentives under alternative climate and economic conditions. Outputs will be used to collaborate with land conservation managers when comparing strategies for ensuring that lands providing high wildlife, habitat and hunting benefits at low conservation cost are conserved while private landowners are happy to forgo land use alternatives.

Capacity-building in the NC CSC Domain

Capacity-building Team

PI: Dennis Ojima, Colorado State University
Capacity-building Leads: Geneva Chong, USGS and LCC Liaison; Brian Miller, CSU Research Scientist
Collaborators: Bob Gough, Intertribal Council on Utility Policy; Dan Wildcat, Haskell University; Jeff Morisette, USGS; Colin Pinney, CSU Natural Resource Ecology Laboratory

In addition to its support for funded projects selected through its solicitation process or the directed funds going to the Foundational Science Areas, the NC CSC also targets funds to support capacity-building work to help the NC CSC achieve its mission. This project supports work that builds capacity among stakeholders that have been otherwise left out of the major projects funded by the NC CSC. The objective of this project is to focus on stakeholder capacity building with two activities related to enhancing tribal capacity in understanding and adapting to climate variability, and a third activity to provide technical support for phenology cameras (or PhenoCams) at multiple locations within the NC CSC domain.

During the course of the project, they added the goal of providing climate education opportunities. They made this change in order to capitalize on an opportunity to improve outreach and capacity building by leveraging training that was already being implemented by the U.S. Fish and Wildlife Service National Conservation Training Center (NCTC).

PhenoCams and Wildlife Migration

In conjunction with AmericaView (a nationwide partnership of remote sensing scientists who support the use of Landsat and other public-domain, remotely-sensed data through applied remote sensing research) StateView partners and the National PhenoCam Network, the NC CSC is supporting the deployment of PhenoCams in Colorado, Kansas, Montana, Nebraska, North and South Dakota with an additional camera deployed in Wyoming in collaboration with the WLCI.

In 2014, two PhenoCams were deployed in collaboration with South Dakota's AmericaView program and the USGS Wyoming Landscape Conservation Initiative's Effectiveness Monitoring Project. The partnership provided research and design for future deployments at off-grid sites alongside the South Dakota instrument garden at the Earth Research Observation Science Center. Additional PhenoCams will be deployed in Colorado, Iowa, Montana, Nebraska, North Dakota, and Wyoming in 2015. The primary accomplishment during this initial work was developing the proper configuration for power from solar panels and internet communications via cell phones, which will allow for PhenoCam deployment in remote areas. Current and archived images as well as data and analysis tools are available at the PhenoCam Website.

Tribal Capacity Building

The concept behind the indigenous phenology capacity building work is to offer tribal college and university mini-grants to develop student phenological and meteorological observation projects in order to document the impacts of climate change and contribute to the student activities within the larger national effort of Indigenous Peoples Climate Change Working Group. The NC CSC's work with the Indigenous Peoples Climate Change working group aims to establish an Indigenous Geography Phenology Network that will provide support to tribal college students to collect phenological observations for culturally significant plants and animals. Participation in the National PhenoCam Network with StateView partners provides an additional direct connection with phenology measurements and the National Phenology Network.

Educational Opportunities

The NC CSC is providing climate education opportunities and training through cooperation with the National Conservation Training Center (NCTC). The NC CSC is collaborating with the NCTC to provide regional offerings of climate-related courses, which greatly reduces travel costs, eliminates tuition cost for students and covers travel costs for those who require it. In April 2014, we hosted the NCTC Climate Change Vulnerability Assessment class (ALC3184) in Jackson, WY. We had 35 students from our region, HI, AK, CA, and UT, and we look forward to collaborating with the NCTC and the US Fish and Wildlife Service Landscape Conservation Cooperatives (LCCs) in September in LaCrosse, WI. We are excited to develop opportunities for ongoing engagement with our user community through this venue. Currently, the NC CSC plans to partner with the NCTC to offer a tribally-focused "Climate-Smart Conservation" course in Rapid City SD, July 28-30, 2015.

Other NC CSC Activities

The NC CSC also supports and leads smaller in-house projects and activities that help us to achieve our mission. 2014 activities have included:

Joint retreat of NC CSC, WWA, and Northern Plains Climate Hub

The NC CSC, Western Water Assessment (WWA) and Northern Plains Climate Hub (NPCH) met for a joint and collaborative retreat on November 6-7, 2014 in the shortgrass steppe outside of Fort Collins to set a collective vision and direction for future work. Attendees included representatives from our Foundational Science Area teams, and staff from each of the organizations.

Development of a Quarterly NC CSC Newsletter

The NC CSC has developed a new quarterly newsletter, with the first Fall 2014 issue released in September 2014 focusing on Adaptation. This quarterly publication highlights various aspects of the work that the Center is doing in each of the Foundational Science Areas and Capacity Building, and introduces the public to the NC CSC team, their publications and work, and upcoming opportunities for involvement.

NC CSC Monthly Check-ins

The NC CSC holds monthly check-ins during the fall and spring CSU semesters to feature a presentation by one research team, and allow updates from all research projects for the shared benefit of all NC CSC and project personnel.

Contributions to semi-annual SAHM trainings (Capacity Building)

NC CSC staff members Colin Talbert and Marian Talbert collaborate with the US Geological Survey to

hold semi-annual trainings on using the Vistrails habitat modeling software at the USGS Fort Collins RAM facility.

Project Management and Reporting

The NC CSC team has established USGS Confluence project management pages for each individual project team, to act as a content and deliverables management system. The pages include timelines, expectations and upload capacity, and provide an opportunity for teams to customize their use to project needs if they wish. This has allowed us to better monitor progress and delivery of expected reports and other deliverables of multiple projects. The monthly check-in updates also give projects and opportunity to inform the NC CSC of progress, updates and changes in action plans. Projects are required to submit a written annual report, and will begin submitting quarterly updates in 2015. Confluence is also being used by the NC CSC directly to manage staff pages and other administrative work.

Preparation for 2015 Open Science Conference

The NC CSC will be hosting its first Open Science Conference May 20-22, 2015. The theme of the conference is, "Integrating Research and Management of Change from the Mountains to the Plains." Preparation for the conference began in 2014 with invitations sent to potential keynote speakers, arrangements set for meeting space, and communications with NCCWSC on conference and travel allowances. We also began planning and monthly calls with an Organizing Committee (J. Barsugli, W. Day, J. Derner, A. Hansen, D. Ojima and J. Morisette) and NC CSC Conference Coordinators (Lead: J. Lackett).

Website Refresh

In the fall of 2014 the NC CSC shared the hire of a website design and maintenance person with SoGES, who works 20% with the NC CSC. Meetings with the web designer has led to a refresh and restructuring of the NC CSC's ReVAMP website at www.revampclimate.colostate.edu.

Communications Shared Hire with SoGES

The NC CSC has collaborated with the School of Global Environmental Sustainability to hire a shared communications specialist, Leeann Sullivan. Leeann will work with the NC CSC on information releases, helping us to convey messages to the public and other audiences.

NC CSC Office Expansion

The NC CSC has completed a planned expansion that will provide more desk area for staff and students, a larger meeting space that is equipped with a smart monitor and conferencing system, and two work areas for visiting researchers.

NCTC Trainings

Brian Miller has gone through training and is now serving as an instructor for the NCTC "Climate Change Vulnerability Assessment" course.

Modeling Activities

Tom Hilinski is working with Dennis Ojima and Bob Flynn to perform NC CSC-region simulations at 1k using Daymet weather, developing a workflow for configuration. He is also working with Colin Talbert to look at VisTrails compatibility to connect to various remote high performance computing systems.
Colin Talbert is developing VisTrails workflows to iterate over a range of climate inputs using byGDP calls, currently applying to the SAHM tutorial, and is providing SAHM VisWall, and RAM support and debugging. Colin is also obtaining and preparing local (Fort Collins Science Center) copies of high-value

datasets, including Daymet, CMIP5 BCSD, Maurer Observational, PRISM 4km, Worldclim, WRF, and topowx. He specializes in building tools/workflows to process local climate data to derive custom climate products, metrics and analyses that are required by partners using python, untimately to be proted to a VisTrails platform for wider distribution.

Marian Talbert is providing continued support for the software for assisted habitat modeling (SAHM). She is also developing code to pull climate data and generate climate primers for national parks and other organizations and partners. Marian is writing, with Colin Talbert, a USGS CIDA FY15 proposal to deliver a 'climate primers' ArcMap toolbox to make more widely available the technique that she is using to develop these climate primers.

Brian Miller is creating a preliminary state-and-transition model of sagebrush steppe dynamics, and updating a state-and-transition model of whitebark pine dynamics in the Greater Yellowstone Ecosystem (adding mountain pine beetle habitat suitability surfaces and exploring management scenarios) for the NC CSC.

Participation in writing and roll-out of the 2014 National Climate Assessment NCANet

Shannon McNeeley and Dennis Ojima contributed to the 2014 NCA

NC CSC staff climate-related Publications:

- Bierbaum, R., Smith, J., Lee, Arthur…..**McNeeley, S.M**. et al. 2014: Adaptation, *U.S. National Climate Assessment 2014*, U.S. Global Change Research Program
- Gordon, E., R. Klein, V. Deheza, and **S. McNeeley**, 2014: Chapter 5 – Water Sector. *Colorado Climate Change Vulnerability Study*, E. Gordon and D. Ojima, Eds., Boulder, CO and Fort Collins, CO.
- Rose et al. (2014). Ten Ways Remote Sensing can Contribute to Conservation.
- McNeeley, S. & H. Lazarus (2014) "The Cultural Theory of Risk for Climate Change Adaptation" (in Weather, Climate and Society, Volume 6: Issue 4)
- McNeeley, S. (2014). A "toad's eye" view of drought: regional socio-natural vulnerability and responses in 2002 in Northwest Colorado DOI: 10.1007/s10113-014-0585-0 - AVAILABLE ONLINE: http://link.springer.com/article/10.1007/s10113-014-0585-0?sa_campaign=email/event/articleAuthor/onlineFirst
- Biagini, B., R. Bierbaum, M. Stults, S. Dobardzic, and S. M. McNeeley (2014). A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility. *Glob. Environ. Chang.*, doi:10.1016/j.gloenvcha.2014.01.003. AVAILABLE ONLINE: http://linkinghub.elsevier.com/retrieve/pii/S0959378014000065

Student and Early Career Training

During 2014, NC CSC actively contributed to the training of at least 21 graduate and undergraduate students and post-docs:

NC CSC Staffing:

- Amanda Weber (CSU, undergraduate student)
- Brigid McCreery (CSU, undergraduate student)
- Brian Miller (CSU, postdoc)

FSA Adaptation project:

- Tyler Beeton (CSU, PhD student)
- Shannon McNeeley (CSU, postdoc)

FSA Impacts project:

- Arjun Adhikari (MSU, postdoc)

Surrogate species:

- Valerie Steen (CSU, PhD student)
- Helen Sofaer (CSU, postdoc)
- Gordon Reese (Fort Collins Science Center, postdoc)

White bark pine project:

- Tony Chang (MSU, student)
- Regan Nelson (student)
- Erica Garroutte (student)
- Nathan Piekielek (MSU, postdoc)
- Kim Szcodronski (student)
- Kristin Kane (graduate student)
- Helen Sofaer (CSU, postdoc)
- Valerie Steen (CSU, postdoc)
- Daniel Schlaepfer (postdoc)

SW Colorado project:

- Carina Wyborn (UMT, postdoc)
- Patricia Orth (CSU, PhD student)
- Katherine Clifford (CU, PhD student)

North Central Climate Science Center on the web
http://www.doi.gov/csc/northcentral/
http://www.revampclimate.colostate.edu/
Reports:
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